DURABILITY, USE AND RE-USE OF BUILDING STOCK

PLEA 2015
BOLOGNA, ITALY
09-11 September 2015

DURABILITY, USE AND RE-USE OF BUILDING STOCK

Fig 1: Social housing in the Turin area managed by Territorial Agency for the House (ATC Torino)

Research summary

A substantial share of the building stock in Europe is older than 50 years. Many buildings in use today are hundreds of years old. More than 40% of our residential buildings have been built before the 1960s, when energy building regulations were very limited. The energy consumption and emissions are actually very significant. The refurbishment and renovation of the building stock is the main issue in the government agenda. Furthermore the maintenance and refurbishment is the most important activity of the European construction sector. Nevertheless the regeneration of housing estates of our suburbs is a complex topic common to major European cities. The decision to refurbish or demolish and rebuild the large building stock built during the sixties and seventies of the last century requires a deep evaluation of social, economic and technological issues. The buildings, in particular the public and social housing, are mostly obsolete in terms of layout, energy performances and durability. The topic of refurbishment of public housing is very complex and also the technological aspects are becoming more significant facing the challenge of energy consumption and emission reduction and accomplishing sustainability.

One of the most important issues to allow the responsible use of natural as well as financial resources is the feedback from building use and operation to the design.

The lack of information about the service life of buildings can be overcome by design tools and procedures to evaluate durability and performances of the building and components over their life time. The research suggests the use of methods of analysis of Failure Modes and Effects Analysis (FMEA) to develop a procedure for the service life prediction and prevention of defects. Through the model the reliability of such data is properly managed by a probabilistic approach and the probability of failure related to environmental agents, users, quality of materials and components, design options and workmanship skills is estimated.

Keywords: building refurbishment, building envelope, FMEA (Failure Mode and Effect Analysis), Durability, Service Life Planning, defect, ETICS (External Thermal insulation Composite System).

1. Introduction

The paper reports the first result of an ongoing research on forecasting methods of the durability of the building envelope. In particular of the ETICS - External Thermal Insulation System Component.

The research, funded by European POR-ERDF programme, shares a Building Technology research team by the Department of Architecture and Design of the Politecnico di Torino, the ATC Torino, a Public Agency owning a large residential building stock, and a number of small construction firms.

The research work has been developed from an FMEA analysis carried out on a generic building envelope mainly by literature data and experience of the research team. The recurring pathologies and degradation mechanism affecting the facades have been related to a probable root cause according to scientific literature (Ximenes, S., de Brito, J., Gaspar, P.L., Silva, A., 2014).

Four agents have been identified as causes affecting the building envelope degradation: design, quality of materials, workmanship skills and external environment.

Some of the degradation phenomena described with the FMEA was observed on a sample of buildings by the ATC Torino building stock. The buildings adopt the same building envelope technology and were built or refurbished in different years.

Data was collected through a quick survey aimed to assess the defects of the facades and their spread.

The condition report results are compared to the usual wear and tear of a facade with a given age and the presence of the building pathologies is identified in the single building considered.

The lifespan forecasting of the facade showing a pathology is developed in a focus group with experts. The probabilistic evaluation of the risk for the degradation was carried out with the support of the Department of Mathematical Sciences at the Politecnico di Torino.

On such premises, a first version of a model has been developed for the service life estimate.

The goal is, on one hand to provide support in the design phase of thermal insulation retrofitting of existing buildings as well as in the design of new buildings and on the other, to allow a better building maintenance planning. The aim is to reduce pathologies by a good design and construction and to reduce the total cost during the whole life cycle of the building. This is particularly important for a public building owner like the ATC of Turin that owns about 31.000 apartments.

In the residential building stock construction and refurbishment design mistakes, little in-depth technical knowledge and lack of coordination in the pipeline led to results very far from those expected, with economic, environmental and social damages that can sometimes be very important. The current economic situation and the increasingly strict requirements of environmental protection require to improve the quality of building works. This process, beyond the skills of the construction firms, requires a greater ability to plan, design, control and long-term monitoring of the design options.

The study of the behaviour of the building envelope during its service life is one of the topics of research in terms of forecasting of operating costs, maintenance and environmental impact of the construction process. In that way the identification of the liabilities by each actor of the process and the quality improvement of the process itself is made possible.

2. Research objectives

In Italy, the first external insulation of building envelopes (ETICS) date back to the early 80's of last century, following the energy crises since the 70's.

The technical literature indicates the reference service life of this solution to 30 years. This value represents, according to European Standard, the threshold limit below which a building envelope insulation system cannot be considered well designed and executed.

Through the observation of many cases in the literature it has been seen, however, that this value can sometimes be overcome and also shifted towards 35-40 years.

Routine maintenance, the technological evolution of materials and components and a more accurate design could probably further improve in our climate and the useful service life of ETICS. The development of this research and the collection of data once applied, will allow the whole building stock of ATC, to evaluate better each degradation mechanism of the building envelope. Such data is actually rarely available. The main goal of this research is therefore to provide a tool for the evaluation of the durability of design and material options used in the building envelope. Such a tool can give to the mantenaince planner and designer useful information through the probabilistic simulation.

2.1 Case studies

The case studies were selected within the building stock owned by ATC within that with ETICS building envelopes. The sample of buildings is mixed by age but adopts the same technical solution, some 80 buildings in 5 areas.

Each building was described in a sheet and data was collected. A photographic survey was carried out to identify defects of the facades.

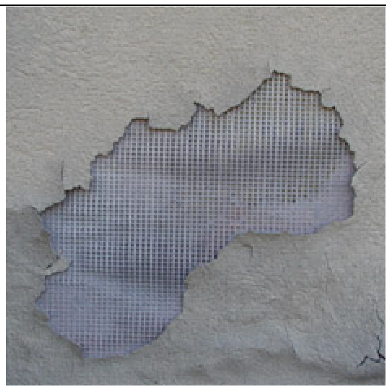
The spread of the defects was recognised in an expeditious way through a specific evaluation procedure.

2.2 Defects of ETICS systems

The FMEA analysis carried out on a generic ETICS system allows the setting of the possible defects of the facade and of the singular points of the building envelope.

The main defects considered in the study are shown in the following pictures.


Chromatic alteration


Peeling

Surfacing

Cracks

Washout

Biological film

Fig 2: The main defects considered in the study.

3. Method

3.1 The FMEA approach

The goal of the model is the early detection of defects of the building envelope, in particular of ETICS, and the forecast of its durability.

The main barrier to this achievement is the cost and difficulties related to a systematic technical survey of the building stock. To overcome this barrier the model shares a simple procedure of defect detection with the FMEA approach.

The following flow chart shows the evaluation process of the specific fault occurring in a building facade system like the ETICS. The single degradation mechanism is investigated and the extent of defects, its causes and consequences are considered. The model is divided in two sections and allows the evaluation of every defect or alteration of the facade. Each defect as cracking, chromatic alteration, peeling etc. is evaluated separately. In the first part of the model the technical staff of the building stock owner carries out a quick survey of the building identifying age of the facade, widespread of the defect due to the specific failure mode in terms of class of damage (i.e.: single damage - less then 20% of the facade - , early defect - 20 to 40 % of the facade - , medium spreading of defects - 40 to 60% - , large spreading of defects - 60 to 80%), part of the facade or single point involved (i.e.: top of facade, base, corner etc.). The second part of the model is developed by a team of experts that identifies causes (i.e.: quality of materials and components used in construction, design features, environmental factors, worker skills) and consequences of the defect in terms of reduction of the Estimated Service Life (ESL).

The output of the evaluation carried out by the model is the identification of the defects related to degradation process other than the regular wear and tear. The alteration level identified by the technical staff allows the model to estimate if the degradation level matches the expected level by the age of the facade. If it doesn't the defect is evaluated according to the expert judgement and the reduction of the expected service life stated.

The relationship between building age and extent of defect comes from the survey carried out in the research considering a sample of about 300 building facades in the Turin city area.

In such a way, we can identify the relationship between the age of the facade (and building) and the extent of defects. Factors like the building exposure to the environmental agents has to be considered. The result of the evaluation procedure developed is then the knowledge of the expected service life of the building facade subsystem in this real environment and conditions of use. The behaviour is often related to the building age, or to the facade subsystem age if refurbished, being related to the degradation processes due to the degradation factors and wear and tear.

The defect extent out of a reasonable range is probably related to infant failures. For such a case expert evaluation is requested to forecast the ESL shortening, as well as the maintenance needed to preserve an acceptable operation standard.

Moreover the collection of data will allow a more accurate lifespan forecasting coming from different design and materials options.

The sample of buildings investigated is still small because of the time required for the model development. Moreover the collection of data about the age of completion of buildings and of the ETICS facades is not so easy in a large building stock as the one investigated. Most of the facades actually have been realised as a retrofit of existing buildings.

The focus group shares two quantity surveyors from ETICS firms, one from a construction firm and one from the maintenance staff of the public owner of the apartment buildings investigated.

3.2 The model

The model based on a probabilistic approach and the application of a simulation using the Monte Carlo method has taken into account the pathological origin that is not related with the normal process of wear and tear detected by the technical survey.

The new values of estimated service life defined on the basis of expert judgment in relation to the cause of the defect has been simulated according to the following procedure:

i: risk factors
1: Chromatic alteration
2: Peeling
3: Surfacing
4: Cracks
5: Washout
6: Biological film
T_0: RSL (Reference Service Life: 30 years)
T: ESL by model
R_i: RSL reduction
x_i : building judgment
$s_i = h_i(eta)$ physiological degradation factor

Through observations is estimated function of physiological deterioration in the form:

$$h_i(eta) = \alpha_i \exp(b_i \cdot eta) = \exp(a_i + b_i \cdot eta)$$

The coefficients α_i and b_i are different for each risk factor and estimated through a passage in linearization of the function and resulting linear regression.
It is defined a tolerance limit, according to age, beyond which degradation is pathological.

$$l_i(eta) = \exp(a_i + b_i \cdot eta + c \cdot s_i)$$

It is defined

$$T = \min\{(T_0 - R_i)_+, i = 1, 2, \ldots 6\}$$

where:

$$R_i = S_i \text{ se } x_i \geq l_i(eta)$$

or:

$$R_i = 0 \text{ se } x_i < l_i(eta)$$

S_i it's a random size with normal distribution of media

$$\mu_i = (\max_i + \max_i) = 2$$

and standard deviation

$$\sigma_i = (\max_i - \max_i) / 5$$

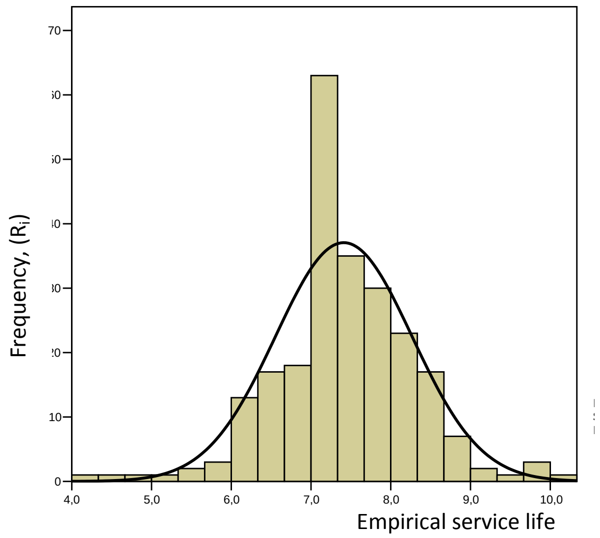


Fig 2: Example of reduction of ESL.

4. Results and design potential

The model provides a first assessment of the physiological degradation rate of ETICS systems built in recent decades in the Turin area, with specified climatic and use conditions. The main modes and causes of faults were identified.
Further development of the survey through the feedback will provide further guidance for both maintenance and for new retrofit.

5. Future implementation

This research could be implemented either through a more thorough assessment of the consequences of defects on the system failures and functionality (aesthetic quality, energy consumption etc.) and enhancing the data base useful for design tools such as BIM.
The forecasting model will increase the accuracy of its output with the widespread to a bigger sample within the building stock of ATC. The causes of the defects and liability will be more easily identified and the quality of design and construction improved.

6. Conclusions

The research, based on a simplified and quick survey procedure, has allowed a first assessment of the service life of facade systems ETICS built in Turin in the last decades. The values of estimated service life obtained are consistent with data from the scientific literature.
The methodology, which will be further tested in the development of the research, also allows to estimate the probability that the facade

system reduces its useful life due to building pathologies.

In the cases investigated, three buildings among the five districts showed pathological phenomena resulting in a significant reduction of life expectancy. In two cases the defects can affect the functionality of the façade system, and in one case can compromise the characteristics of appearance.

7. Acknowledgments

Authors would like to express their special thanks to Territorial Agency for the House (ATC Torino), for the information provided to the study. Special thanks to Prof. Franco Pellerey and Prof. Donatella Marino to support the development of the forecasting model.

8. References

Baroth J., Breysse D., Schoefs F., (Eds.). 2011. Construction Reliability – Safety, Variability and Sustainability, Wiley, Hoboken, ISBN 9781848212305

ETAG 004 Guideline for European Technical Approval of External Thermal Insulation Composite System with rendering

Pollo, R. 2006. Service Life and LCC Assessment. The use of FMEA As Design Tool in A. Talon, J-L Chevalier, J. Hans, CIB W080 Prediction of service life of Building Materials and Components. ISBN 9063630522

Talon, A., 2005. Temporal quantification method of degradation scenarios based on FMEA, 10 DBMC International Conference on Durability of Building Materials and Components

Ximenes S., de Brito J., Gaspar P.L., Silva A., 2014 Modelling the degradation and service life of ETICS in external walls

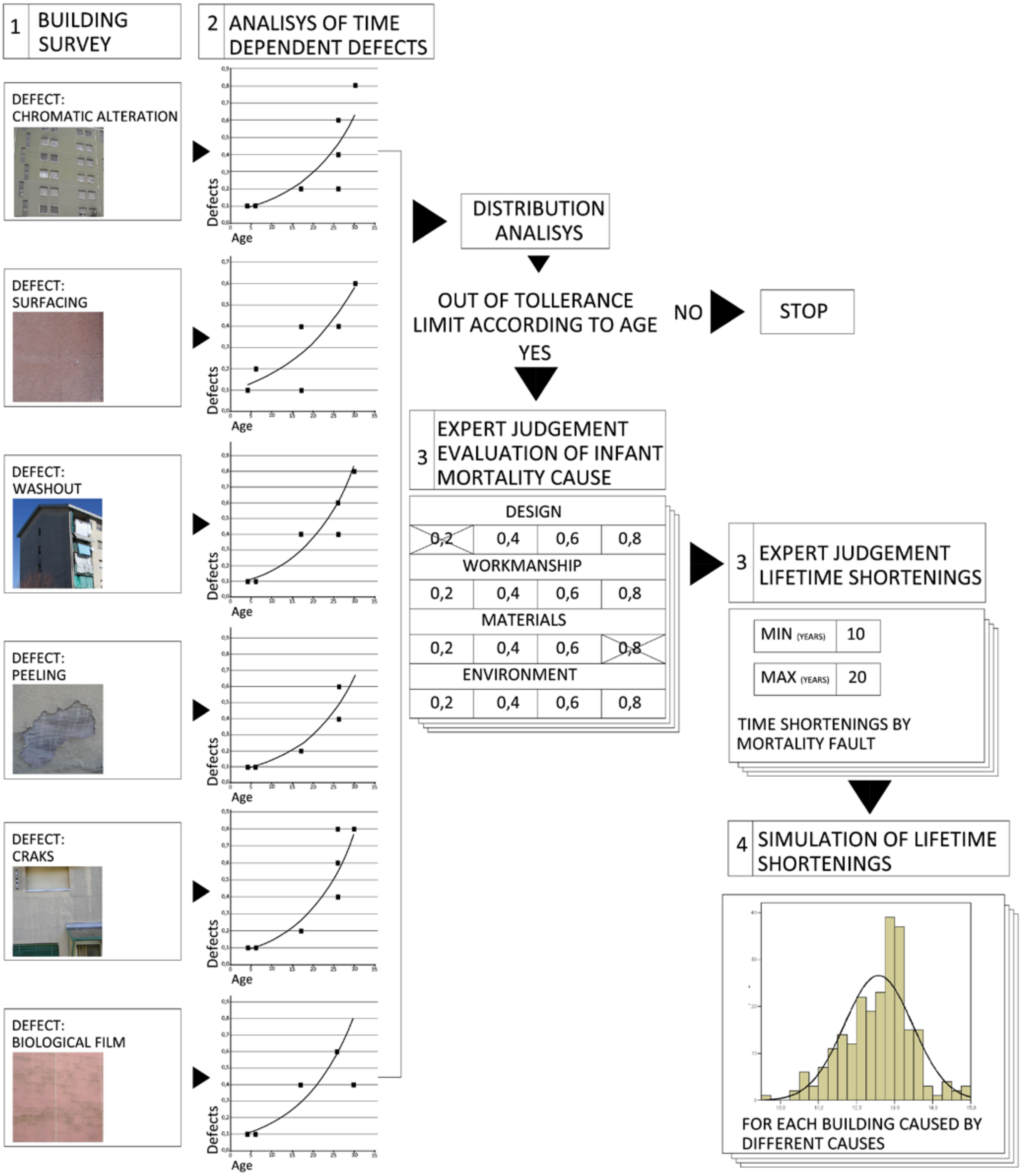


Fig 3: flowchart of evaluation model.